ENGINEERING CASE LIBRARY

ECL 247

THE DESIGN OF A SYNCHRONOUS THINNER

This case is an account of a design that is commercially succesful. The narrative by the engineer presents the problem of thinning young plants and the four distinct iterations he went through to obtain the final design. The resulting patent that was issued is included in the case.

Written by Jerald M. Henderson from a narration by Roger E. Garret, both from the University of California, Davis.

THE DESIGN OF A SYNCHRONOUS THINNER (A)

Preface

This case was developed from a tape recording of Professor Garrett's presentation to my design class. Professor Garrett has been associated with many successful design projects and I asked him to come to my class and discuss with the students some of his design experiences. Before he got into the details of the case which he was going to present, he made a couple of interesting comments. "We as designers never make mistakes, but sometimes we just don't have the problem defined right." He also stated, "when the problem is thoroughly defined then the solution is obvious." The rest of this document is an edited version of what Professor Garrett said to the students.

The Problem

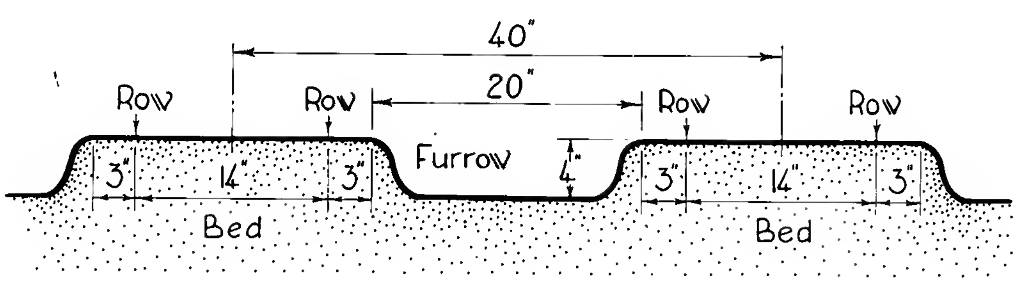
The case that I want to talk with you about is the development of a synchronous thinner. I picked this project for one reason; because it got to where we would like all our designs to get, into commercial practice. The thinner is currently being used and produced. Perhaps that's a little unrealistic because an awful lot of designs will not get to that point. I have had more of my designs fall by the wayside than I care to keep count of.

I was involved when I first came to the University in 1962 with the development of lettuce harvesting. We were concerned with the total system of lettuce production and we realized also that the crews that were then harvesting lettuce by hand were, in many cases, the same crews that were thinning the lettuce and establishing proper plant population. Lettuce is overplanted with the normal rate of emergence of seedlings about 60%. The germination of the seedlings themselves is pretty good, but you don't always get them up. Even if they come up you have other hazards with bird problems, worms, diseases, etc. So, it's customary to overplant and thin to a proper stand of about 10 to 12 inches between plants. There is a minimum spacing for head lettuce. If they get much closer than 10 inches, they won't develop into good heads; they will become skewed or not develop at all into a solid head. So it's important to have a minimum plant spacing; the maximum plant spacing doesn't seem to be critical, but you do need to guarantee the minimum.

I approached the thinning problem partly because it appeared that it might eventually have some applications in lettuce, but also because it appeared to have more immediate application in some other commodities. Broccoli was one that was suggested to me by a farm advisor as being a crop where adequate weed control was available so that if we had some way of identifying plants in the row, the plants could be blocked to leave a minimum spacing between them. Eventually, they hope to get to that point with lettuce. At that time, they were not at this point because weed control was not satisfactory, so we were kind of working ahead of ourselves in lettuce. We looked at some other possible crops but they didn't appear to be too important as far as the use of synchronous thinning is concerned. Sugar beets were being blocked with the so-called random mechanical blockers. There were also moves to go directly to planting to stand so that the need for synchronous thinning did not seem to be very important.

At any rate, I did pursue it from the standpoint of lettuce and with some assurance that it could be immediately used in broccoli. I was given assurance that weeds would not be a problem; we would have a row of seedlings that would be one or two or three inches high and it would be necessary to identify one of those seedlings and separate it from adjacent plants leaving a block of unpopulated area down the row to where the next plant would appear. Exhibit A-1 shows the ideal cross-section for a lettuce bed.

Exhibit A-1



THE DESIGN OF A SYNCHRONOUS THINNER (B)

The Solution

The problem then is knowing first of all when you encounter a plant and secondly then removing a block of plants down the row for some distance which is fixed, but is something you may want to vary from crop to crop. When beginning to search for the next plant, if we come to an area where there are not any plants for a period of time, we would like to be able to wait until we get to the next plant. It's essentially a blocking action, but the blocking is synchronized. That's why I chose the term synchronous. We'd ideally like to avoid leaving doubles but it was recognized at the time that we would have to improve our planting techniques in order for the thinner to work. We probably have to be able to plant with a minimum of 1 1/2 to 2 inches between seedlings in order to be able to singulate the seedlings. So that was a design parameter that we accepted even though at that time it was not normal practice to have that much spacing between plants. Some were at that time coating seeds by putting them in round pellets; the massive amount of coating material tended to inhibit germination. Now they've gone to what is called a minimum coat that gives the seeds an elliptical coating which can be singulated fairly easily and doesn't inhibit germination of the seed quite as much.

So there are several aspects of the problem. First, it's hard to identify the presence of the plant. Once you have done that, how do you remove a fixed block of plants? And how do you get the two working together?

There have been a lot of approaches to sensing the plants. Some have used very sensitive mechanical switches. If you ever go out into the field and touch a plant, they are almost negligible in resistance and it seemed to me that from a practical standpoint, any switch that would be sensitive to the forces that could be exerted on it by a plant, would be overwhelmed by mechanical vibrations from the chassis itself. I rejected any kind of a mechanical switch. Another approach that had been tried by some with some success was a light beam sensing device. I wanted to reject the light beam, and did eventually for the simple reason that getting down to in some cases within a half inch of the surface of the soil and then having the cutting device moving soil, the environment for the light sensing device seemed to me to be too hostile. There would be soil movement and considerable dust in the area. Soil particles would have a tendency to adhere to the surface of the light source or the detector. Just the physical problems of getting a light beam down within a half inch of the soil, which means immediately that the envelope containing the source or the detector cannot exceed a half inch if it is not going to hit the soil surface, appear tough.

I spent considerable hours for that portion of time that you are allowing your thoughts to mature without consciously thinking about them and I remember part of the time walking along and holding a finger out and trying to think, now if something just brushes my finger, what mechanism can I employ that will give me the most sensitive measure of contact. Electrical conductivity occured to me as perhaps the most sensitive. I tried to think of just what's going on in

your finger itself, because you can feel an extremely light touch. I believe your finger senses do respond to some sort of an electrical stimuli in the sensing of pressure, but at any rate, I approached it to see whether there was some possibility of using an electrical contact with the plant, not a switch per se, but electrical contact with the plant itself, in which the plant becomes an active element in the circuit; the plant becomes the switch itself.

There are two ways to approach that. One is to have two conductors and expect the plant material to bridge the gap between them. The other is to use the plant as part of the circuit into the ground and then establish contact with the ground, which seems to me to be a more reliable mechanism because I would only have to have a single point of contact with the plant. Otherwise, I would have to make two simultaneous contacts with the plant. So I chose to design a probe by using a piece of copper tubing connected to an electrical circuit which was then connected to a ground blade. I did a little research on this to check the electrical resistance of plant tissue and found it to be somewhere in the neighborhood of two to five megohms. But, still there is considerable difference between a five megohm resistance and an infinite resistance, and with the appropriate circuitry, you can tell the difference fairly easily. I was fortunate that a few years prior to that the development of field effect transistors had been accomplished. The Department had purchased one of those units for some other work and had spent about $35 for one little transistor. I used it for awhile and eventually replaced it for $1.50. I think they're under that now. Soil conditions seemed to have little effect on my sensing approach.

The probe was just an electrical conducting surface that could be placed very close now to the soil surface, was not particularly subject to damage and, however, was subject to coating. It may be necessary to keep them clean. They actually do have to keep the probes clean that they're using now, but it's not a serious problem.

So I turned my attention then to some mechanisms for cutting out the plants. One of the things you want to do when you're designing something is to try to explore the range of alternatives that are available to you. It will take some power to remove this material and it takes a certain amount of work. The amount of power that's required depends on how rapidly you do the work. By spreading your work out over a long period of time, the power requirements are very low. There's an advantage in picking up the power on a thinning device from a ground engaging wheel. Then you can mount this unit on a tool bar and have very little other connections; they're very easy to mount and dismount from a tractor, so picking power from ground engaging wheels seemed to me to be a desirable characteristic. To do that, I would have to spread my cutting operation out over a long period of time, so I chose to go to a device which was essentially a disk. The patent drawings in Exhibit C-1 near the end of this case illustrate this concept. A disk could be rotated as you move with very little power input because the draft helps to rotate it. So, what I envisioned was a disk that had a notch out of it so that we could move down over the plant row and allow the plants to pass through that opening, but as soon as we detected a plant with a probe that was sitting right behind the disk, we would start rotation. That was then coupled to a ground engaging wheel through a single revolution clutch that will trigger and make one revolution.

That was my first concept, and it worked after a fashion. The first time that I used it, I noticed that there were conditions under which you

could have some very small plants, including weeds, which were too small for the detector to identify. I tried to get rid of those by attaching to the blade another blade that would come along behind the probe. It would actually skim the surface of the soil even though the blade was not rotating, but it was back behind the probe so that as soon as the disk started rotating, it would move out of the way. That was a good idea. Unfortunately, it tended to plow a little soil up and soil would frequently touch the probe and trigger the action of the blade.

There seemed to be several disadvantages with this concept, flexibility of the design and versatility being major flaws.

Another Solution

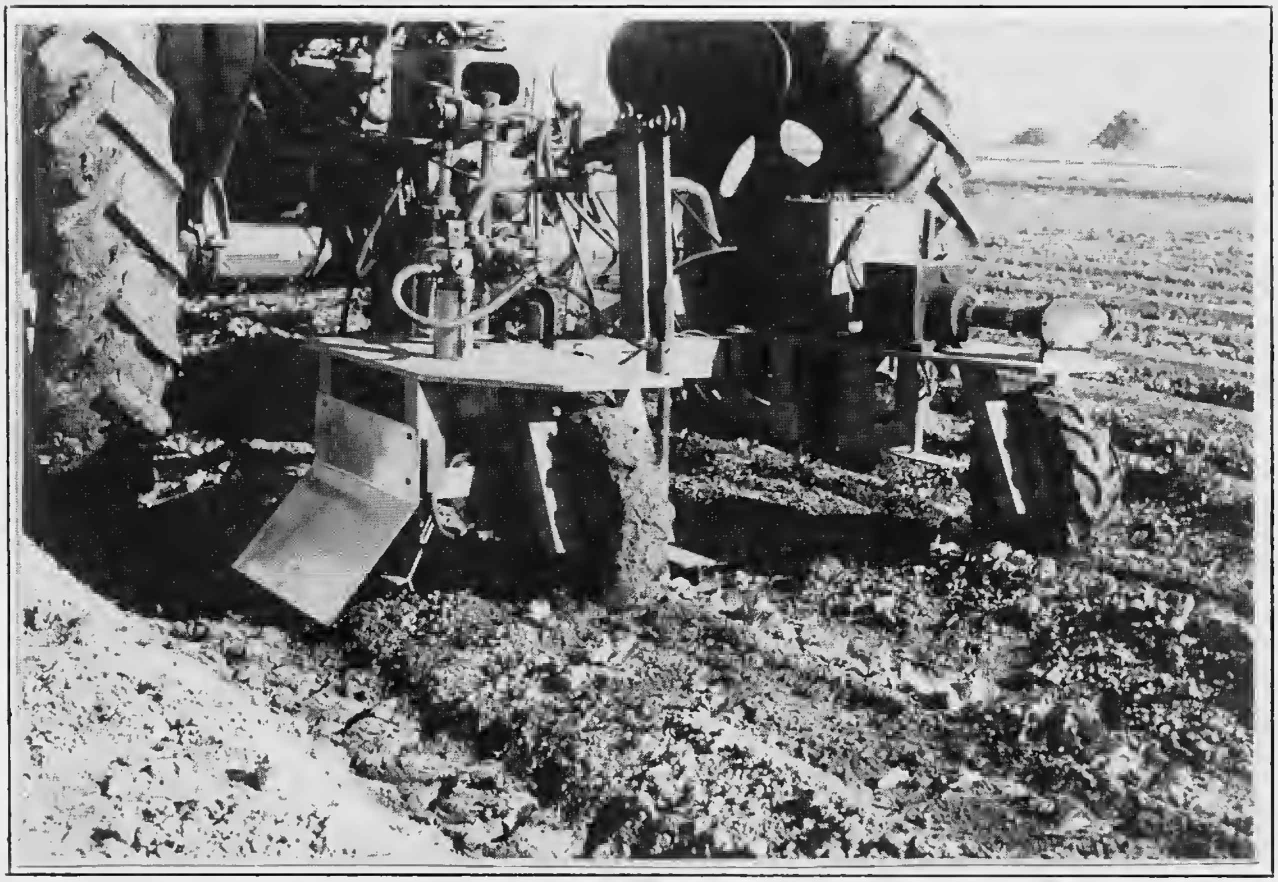
So, I tried to explore the other extreme condition and that is to put all of your power in momentarily, i.e. high power over a short period of time. The concept there is that once you detect a plant, just suddenly block out everything for the next specified distance and then go on down the row until you find the next plant. So I designed another unit which had a horizontal access above the row. A crow-foot blade was attached to an air cylinder so that once I would touch the plant with my probe, the blade would swing across scooping out soil and plants and throwing everything into the furrow. The blade would hold itself in this new position until it contacted another plant and then it switched back again throwing the debris over onto the center of the next row. A guard to keep the blade from throwing material over onto the next plant row was added so the debris was contained near the center of the bed. I built that unit also; see Exhibit B-1.

I even made some attempts then to get back to the problem of picking up those plants that weren't sensed by the detector by making this blade in two sections. I would have a front section which was the major one that would cut out whatever length of plant row I wanted and then behind it, I'd have a probe, and behind the probe I would have another blade that would clean up some of the area that had already been cut. This worked well with one exception; if the soil tended to be a little crusty, it sheared off an entire block of plants. So, this portion of the design was eventually dropped and the problem was ignored. It was not as much of a problem as I had anticipated that it would be.

That brings up another point that you ought to keep in mind--it's good to be inventive as engineers, but don't invent problems for yourself. Wait until you see problems develop before you try to solve them because you can spend an awful lot of time trying to solve a problem that may not really be there. I've seen a lot of instances in which people had essentially invented problems.

The blade is bolted onto the shaft and can be changed to vary the length of the blade so that you get the versatility you want and length of block that you need; all you have to do is change the blade length. For an earlier version of the swinging blade of high power requirement, the probe was a rod coming down onto the row. I found registry with the row was extremely critical and so I turned the tube the other way, and it's now a horizontal tube going across the row instead of coming right down to a single point.

Exhibit B-1



You can see in Exhibit B-1 the kind of soil conditions we were in to be a little bit sticky. This tended to aggravate things. I was having problems with registry on the row from dirt getting piled in front of the wheel, and problems of keeping the probes at the right height. False signals would cause the blade to operate when it shouldn't. I reflected back on this experience later and decided then to go back to this basic design. I was probably the most discouraged person that was associated with the project. The rest of the people who saw it thought it was doing a pretty darn good job. But I was very critical with my design. I think it's good for an engineer to be critical of a design, but I guess you can go too far with anything. The ultimate decisions need to be made by those who are going to apply or use the design.

A Third Solution

On the way back from Imperial Valley where I first tested this device, I designed a third version. I would have a series of little blades, each one inch wide. These would block out soil until I got to a point where I wanted to save a plant. When I detected plants that I wanted to save, then the blades would be routed into a different mode of operation such that they would not cut across the row and I would skip about 3 inches. Then the blades would start slipping across the soil again. I had this designed to have each blade individually cam driven. See Exhibits B-2 and B-3. Each blade followed a cam surface. To achieve this mechanism, I had a portion of the cam cut out and then I had installed a kind of switching device so that I could either let them cut or pass through and not cut. It sounded very encouraging and I did some design work and actually built the unit.

I had several things that I wanted to do with this. The whole thing is supported from the wheel which sits on the center of the bed and drives it. Power is picked up from the center and that wheel has an axis which is the axis of the sprocket. A second wheel has a different axis; the ground gauging wheel and the axis of the thinning wheel itself is offset. By rotating the hub, then you can get a height adjustment with respect to the center of the bed. You've got two sprockets side by side with the double roller chain engaging both of them at the same time. If you move slow enough, this could be made to work, but it's got a basic design problem with it.

This is probably an example of getting ahead of your analysis and not really thinking the thing through far enough. Think of the problem of a freight train going about 70 mph down the track and all of a sudden deciding to switch one of its cars over onto a siding and the rest of them keep on going down the main track. That's essentially what we've got here because at any reasonable field speed the blades were coming around pretty fast. There's one every inch of forward travel. How are you going to get some of them to come one way and three of them go through there and the rest of them through this way without some of them impacting on the divider? When they do, that is the end of that cam. It looked pretty, but after that finally occurred to me I scratched my head for quite awhile and finally decided that I was being super critical of my designs, and this really wasn't fair for me to be that critical if the people who wanted this were not objecting to it.

The Final Design

So I decided that I would back off from being quite so critical. I would

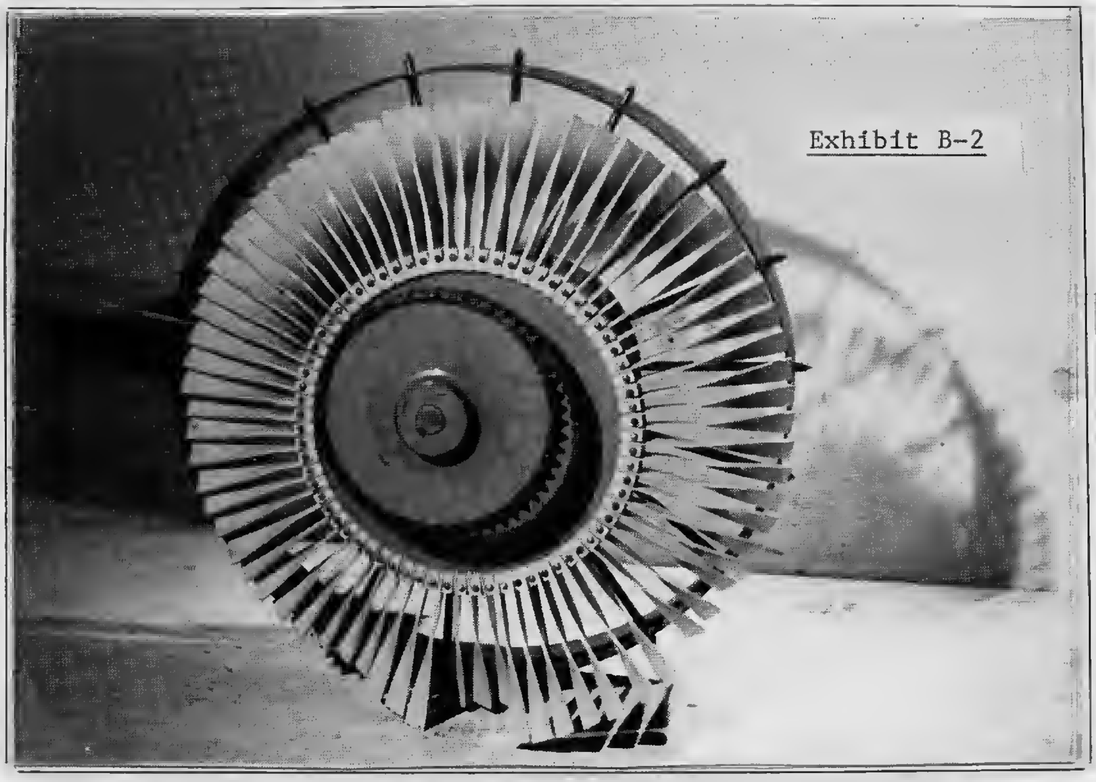
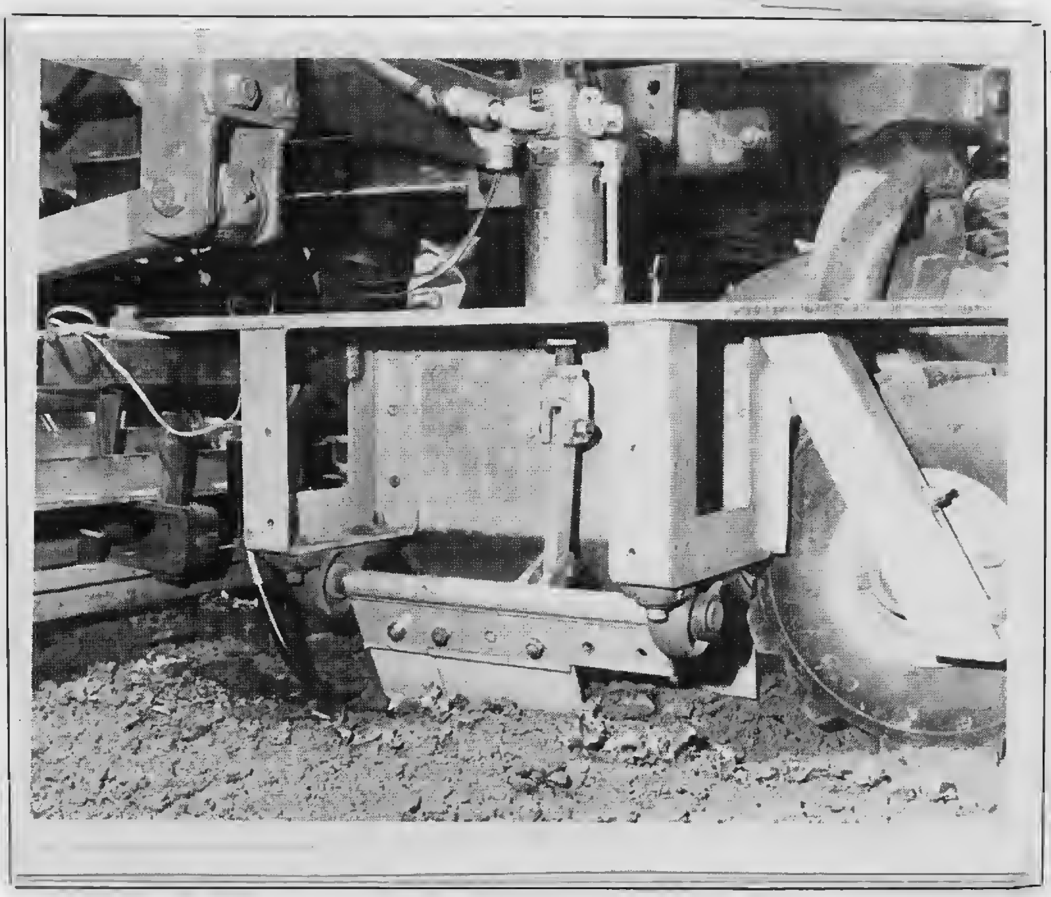


Exhibit B-2


Exhibit B-3

go back to the second design and try to see if I could develop it better and let someone else make the decision if they wanted it or not. wasn't going to try to sell it to anyone, but let them decide if it was satisfactory. I also came to the realization that I was running my thinner backwards. I simply turned the unit so that the gage wheel was in front of the blade and then I don't have the problem of having the dirt being piled in front of the blade. See Exhibit B-4. I've run on to other cases where I've had to turn my designs around. So that's something to keep in mind as well.

Exhibit B-4



MOTION DIRECTION →

I did go back and turn around the second version with a swinging blade mounted on a front tool bar of a tractor. It worked very satisfactorily. I had one occasion to go into a field demonstration that was arranged down in the Gilroy area by a farm advisor in the area. He was going to demonstrate to farmers in his area the state-of-the-art in thinning. He had invited manufacturers of several different types of ramdom blockers that were available at the time to come in and thin a stand of lettuce during his field day trial. Weather conditions had not been too good prior to this date, but you have to schedule field demonstrations, yet you have no control over the weather between the time that you have to schedule them and the time it actually occurs. The lettuce plants were just beginning to emerge; they were at the most maybe a half inch high, and they weren't all out yet. They should have given it another week; they would have had a much larger stand. So it was a very sparse stand, and extremely small plants. The other manufacturer representatives would not go into the field to thin it with their blockers. They knew that there wouldn't be anything left when they got done. There would be some blocks there, and maybe a plant would come up out of them, but they had no way of knowing what was going to be there. I figured I didn't have anything to lose. I went in and tried it. I had a little trouble getting my probe down, but I did manage to get it almost down skimming the surface. I went through and left a respectable stand in the field with my thinner.

Because it wasn't a very good test of the other devices, we went into another field that had not been part of the planting. It was a field of sugar beets and it was long overdue for thinning. The plants were 4 to 5 inches tall draping over the field. I was scared to death of that one because I could see what would happen. The probe would touch a leaf and the blade would cut that same plant because the leaves were so long. It turned out that it didn't work that way....again, I had invented problems for myself. What happened is that the blade moving down the row is close enough to the row that it tends to latch onto those leaves and drag them all forward. So, you're actually thinning a row of plants that are essentially combed forward. This was a cloddy field, very poor conditions and overgrown, and again the behavior of this device was absolutely phenomenal. Much better than I could have anticipated. So succesful that a manufacturer licensed it and this is the basis for John Deere's electronic thinner. See Exhibit B-5. At the present time, this thinner has totally taken over the sugar beet industry which I said it would have no application in, and is still only rarely used in lettuce; not at all in brocolli.

Anytime someone asks you to predict the impact of your work, you might tell them about this case because right to the time that they went into production, I told John Deere, "do not expect to sell this in the sugar beet industry." Fortunately, they didn't believe me. Fortunately for them and for me, too.

Most selective means of mechanically thinning beets

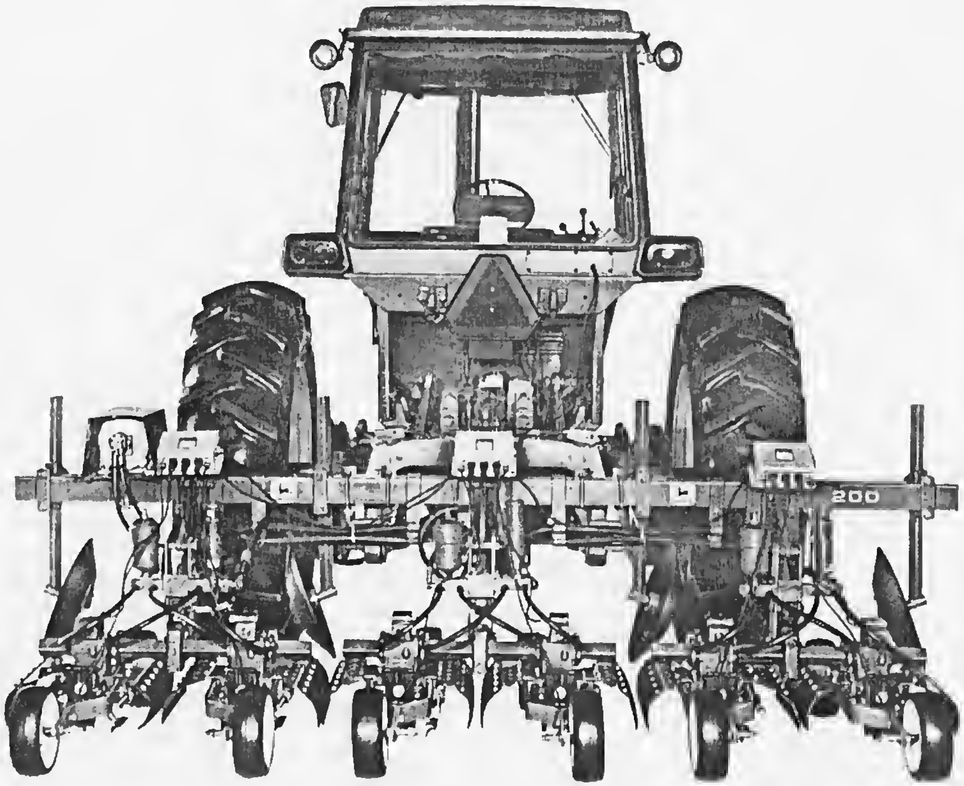
Electronic thinners have long surpassed hand labor in quality and quantity of thinning in a day's time. The new 200 Series Thinners from John Deere add a new dimension in precision thinning and reliability.

Major design changes in the gauging and amplifying systems provide you with a thinner that follows the ground contours extremely well and is less susceptible to malfunctions and false triggering.

Quick, easy adjustments; stronger frames and components; and greater actuator oil capacity add increased reliability to these thinners.

The 200 Series Thinners are designed to handle all types of vegetable crops and cotton as well as sugarbeets. Row spacings 12 to 48 inches, plant spacings 4 to 12 inches, single or double rows/bed —whatever your particular thinning requirements are, the John Deere 200 Thinner adapts to it.

The 6-row thinner shown at the left is only one of many variations offered. 200 Series Thinners come in 2-, 4-, 6-, and 8-row versions with easy, fast adjustments to change row spacings or the number of rows you want to thin.



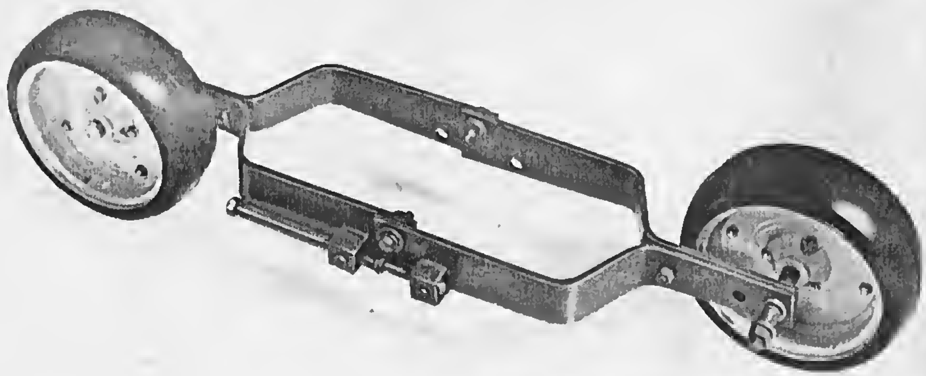
All 200 Series Thinners are rear-mounted and are designed for Category 2 and 3 3-point hitches. They operate on closed-center hydraulics only and the tractor must have a minimum oil capacity of 13-gpm at 2,000-2,250 psi pressure. To change row spacings, you simply loosen four nuts and move the entire thinning mechanism. No more moving of shields, actuators, etc. —all separately.

The above photo shows the knife flashing across the row, wiping out unwanted plants, to provide an even stand for maximum growth. This sequence was triggered when the probe plate came in contact with the plant to be saved. The knife stops after it crosses the row and is actuated again when the probe comes in contact with the next standing plant. (The curved rubber shield was removed in the above photo to show the knife action.)

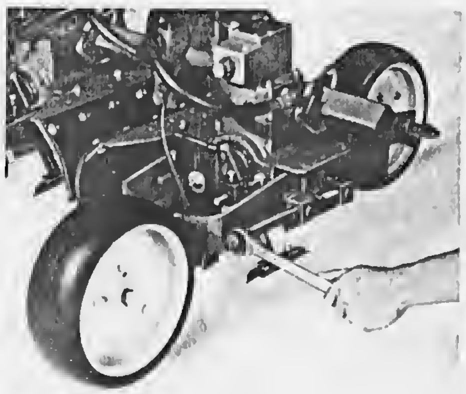
Exhibit B-5

NEW 200 SERIES THINNERS (Continued)

Major design changes in the gauging and amplifying systems give you precision never before available... even from John Deere

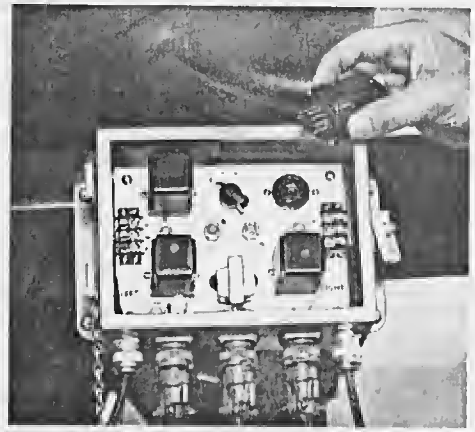


Gauging wheels and frame are designed so the actuator and knife are in the middle of the gauging framework. This lets you position wheels on both sides of the rows for more gauging precision.

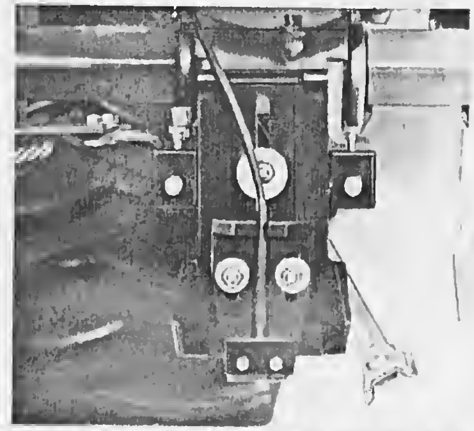


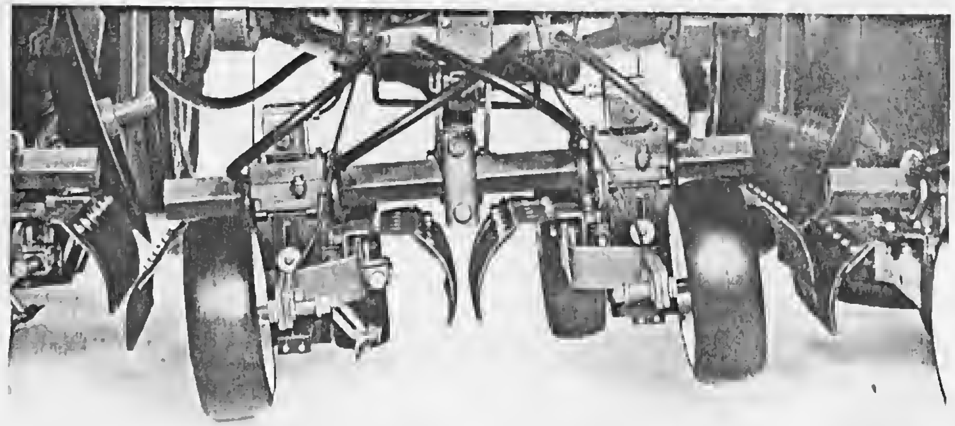
A simple, fast screw-adjustment provides easy, accurate height setting of the gauging system. Each revolution of the bolt raises or lowers wheels .075 of an inch.

Four replaceable components in the amplifying box allow quick and easy servicing in the field. Each control box governs two rows. If one row is malfunctioning, it can be checked by simply switching a component from the adjacent row.



First-stage sensing is now in the probe wire tip . . . the rest of the wire is not highly sensitive to electrical interference or moisture. Quick, simple adjustments let you set the probe plate in relation to the shield to match crop conditions.

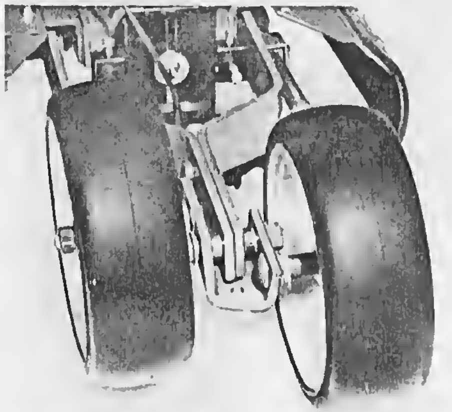




A flexible lateral pivot joint on 2-row/rig units compensates for unlevel bed tops. Oscillation of up to 4 inches is possible on single-row/bed models. A simple adjustment reduces the amount of movement to 1½ inches for 2-row/bed units. Coupled with the new gauging design, the flexibility of the row units aids in following the lay of the land to give that extra precision for a better job of thinning.

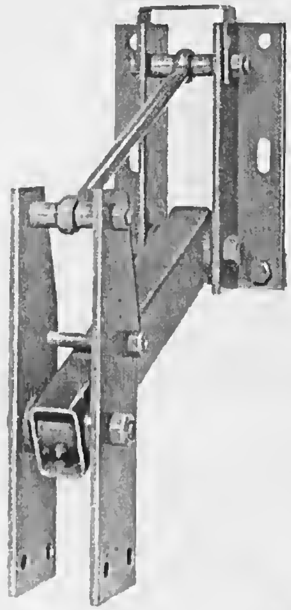
Exhibit B-5, continued

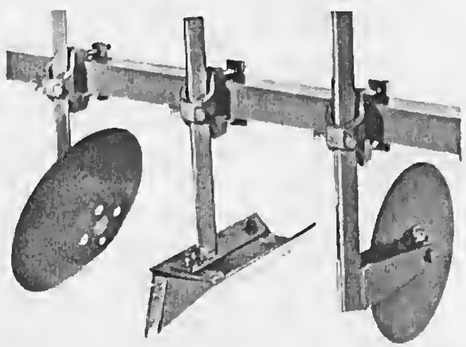
An optional walking gauge beam provides even more ground-following capabilities. Designed for two gauge wheels, the walking beam allows a range of movement that works extremely well in rough, cloddy fields or in extra soft fields.



Rubber-flap shields absorb impact of flying debris and deflect it down, away from the row. Rubber shields do a better job of shedding dirt and mud than metal shields did. The shields adjust independently of the row units.

Optional, single-row/rig frames provide an extra degree of rigidity for those crops in which row movement of thinner rigs must be kept at a minimum. Rig links are made of structural tubing for added strength and rigidity; they pivot smoothly on tapered roller bearings.

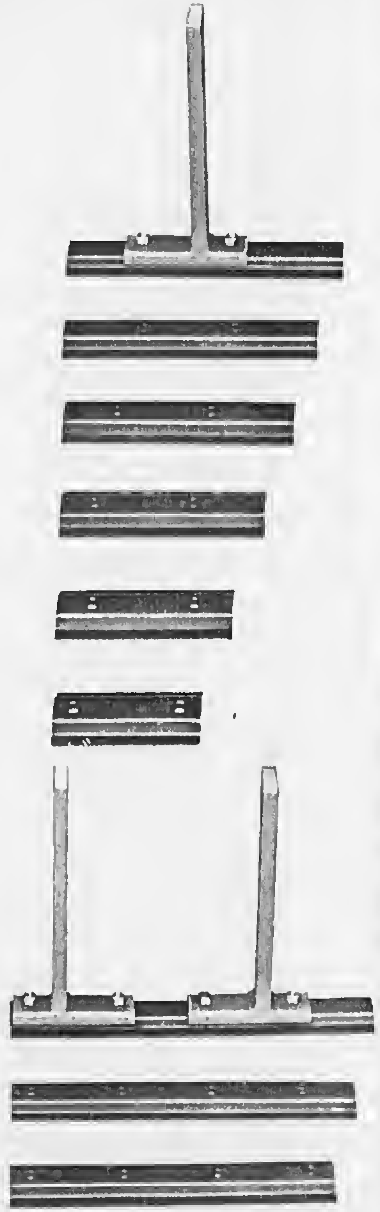




Choose from three guidance systems—cone wheels, rolling coulter, and corrugator—to match your preference and soil conditions.

Exhibit B-5, continued

With knives of nine different lengths available, ranging from 4 inches to 12 inches, you can pick the spacing that best suits your crops or own personal preferences. Knives travel through a 66 degree arc in 28-milliseconds (from time probe senses plant until arc is complete).



SPECIFICATIONS

(Specifications and design subject to change without notice)

Type and Models . . . Selective electronic; for crops planted in single and double seedlines, flatland or bedded; 2-, 4-, 6-, and 8-row.

Operating speed . . . 3 mph

Weight (varies by model) . . . 6-row, rear-mounted, approx. 1,700 lb.

Tractors recommended (see Note 1) 2-, 4-, and 6-row . . . 1020 (see Note 2), 1520, 2020, 2520, 3020, 4000, 4020, 4030, 4230, 4430, 4630.

8-row . . . 2520, 3020, 4000, 4020, 4030, 4230, 4430, 4630.

Note 1: 200 Series Thinners can be used only with John Deere New Generation and Sound-Idea™ tractors with closed-center hydraulics. Tractors must have 3-point hitch and at least one remote cylinder control valve. Note 2: 1020 Tractor must have a 13-gpm pump.

Carrier for attaching thinner to tractor . . . 4x4-inch frame.

Operating controls:

Raising, lowering unit . . . Rear-mounted tractor rockshaft control

Starting alternator and activators . . . Remote-cylinder control valve

Starting and stopping row units . . . Electric switch

(All other operations automatic.)

Knife arc . . . 66 degrees

Knife speed . . . 28 milliseconds (from time probe senses plant until arc is completed.)

Optional equipment:

Interchangeable knives; 4- to 12-inch lengths

Tall-plant attachment; polyurethane flap

Main frames; 144, 170, 194 in.

Guidance systems: Cone guide wheels, rolling coulter, and corrugator

Single row/rig

High-flotation gauging; 2, 3, or 4 wheels per row.

THE DESIGN OF A SYNCHRONOUS THINNER (C)

The Patent

Putting the probe behind the blade adds significant improvements as compared to putting the probe in front of the blade. That was one of the features that was brought out in the patent that is included as Exhibit C-l. It extremely simplifies the design of the device. I found myself almost apologizing for the simplicity of the device and yet simplicity in a design is of the essence. If you get something that simple, you've really got something.

Dec. 19, 1967
R. E. GARRETT
PLANT THINNING MACHINE AND METHOD
OF THINNING PLANTS
3,358,775
Original Filed April 22, 1965
4 Sheets-Sheet 1

Exhibit C-1

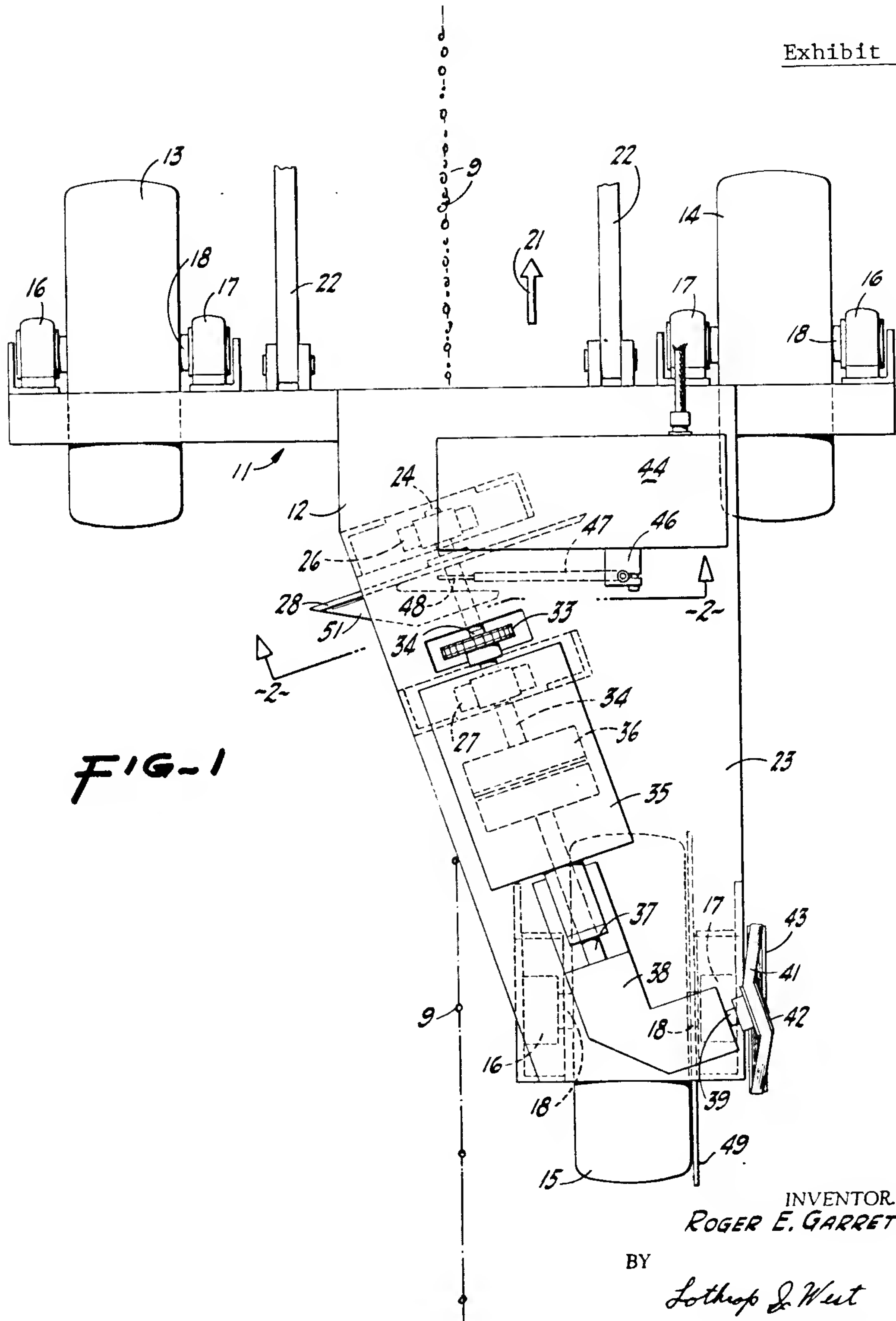


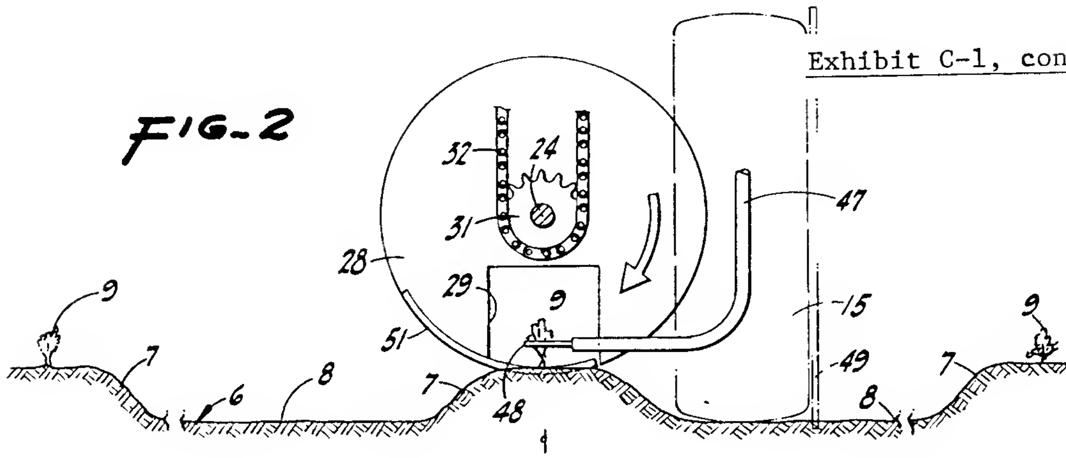
FIG-1

INVENTOR
ROGER E. GARRETT
BY
Lothrop & West
ATTORNEYS

Dec. 19, 1967 R. E. GARRETT 3,358,775
PLANT THINNING MACHINE AND METHOD
OF THINNING PLANTS
Original Filed April 22, 1965 4 Sheets-Sheet 2

Exhibit C-1, continued

FIG-2



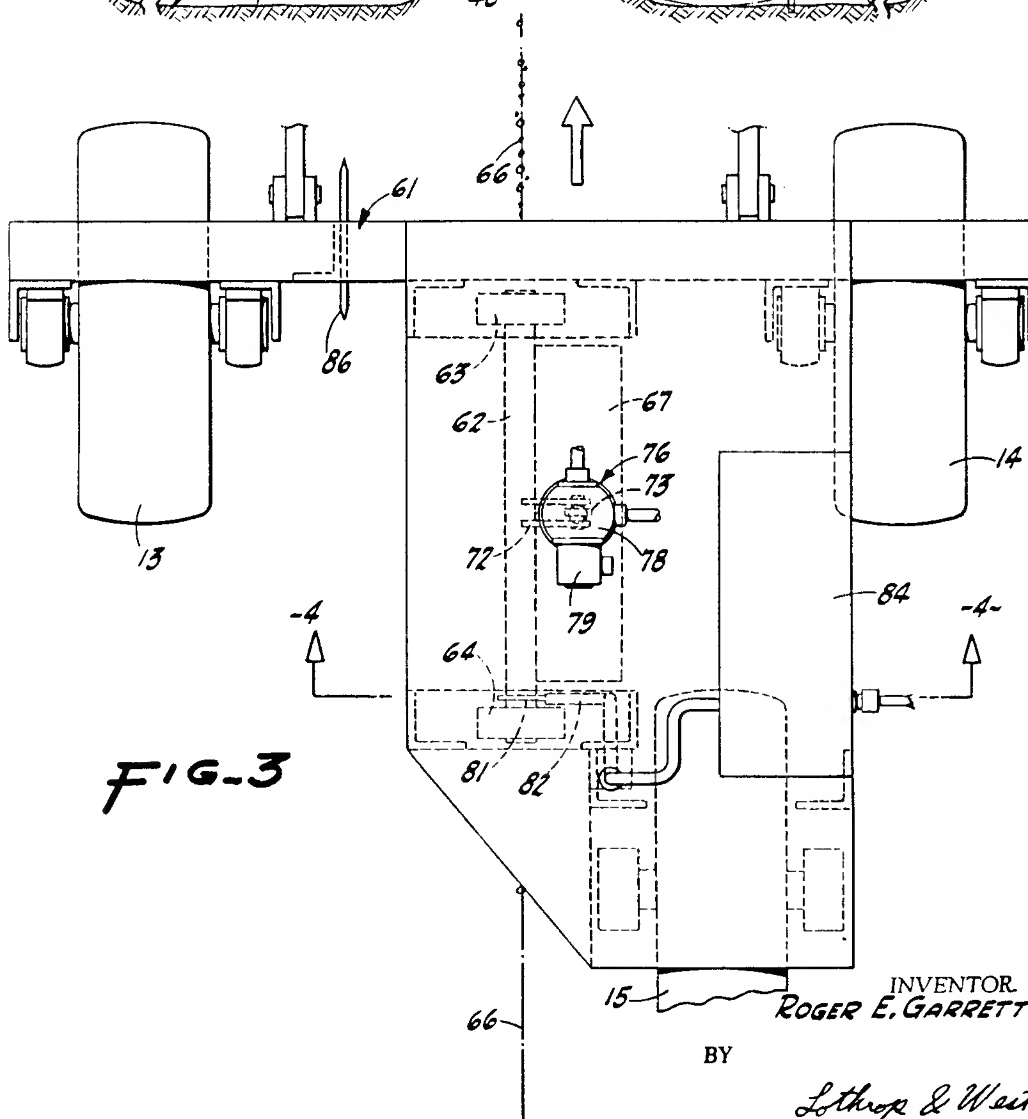


FIG-3

INVENTOR.
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ATTORNEYS

Dec. 19, 1967 R. E. GARRETT 3,358,775

PLANT THINNING MACHINE AND METHOD OF THINNING PLANTS

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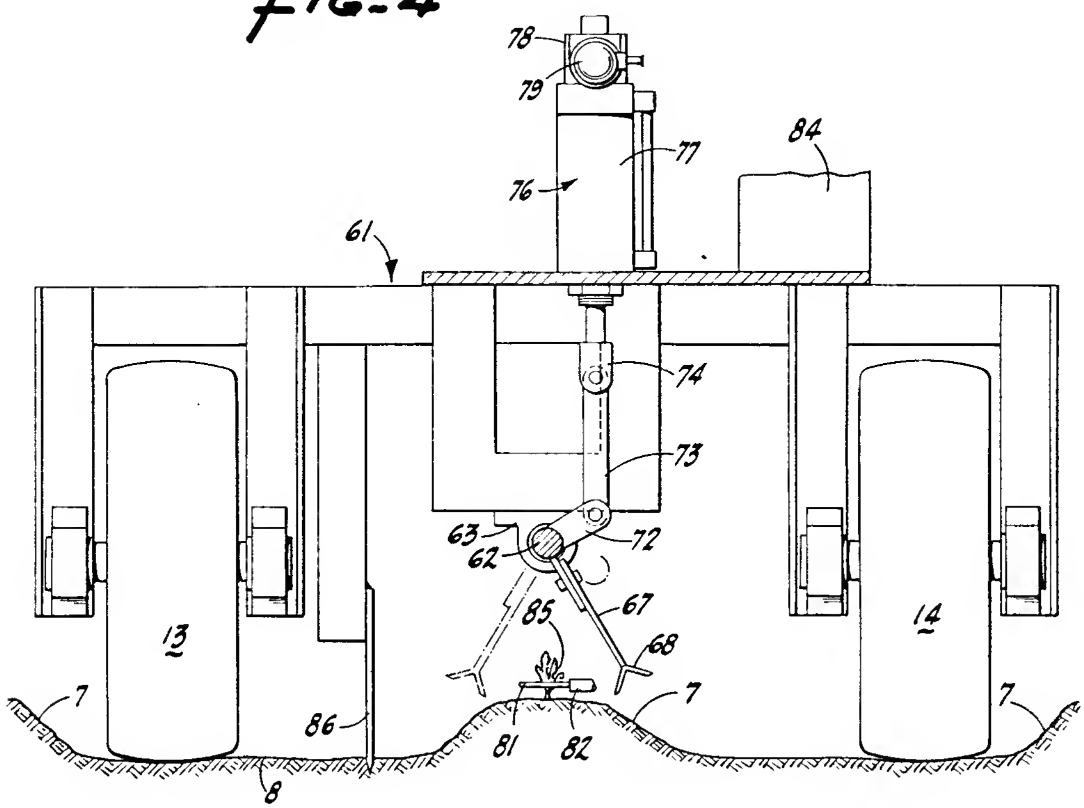
Exhibit C-1, continued

FIG-4



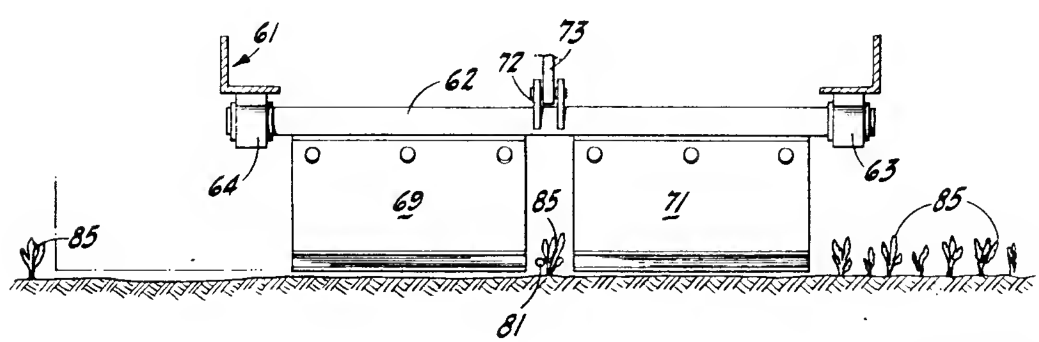


FIG-5

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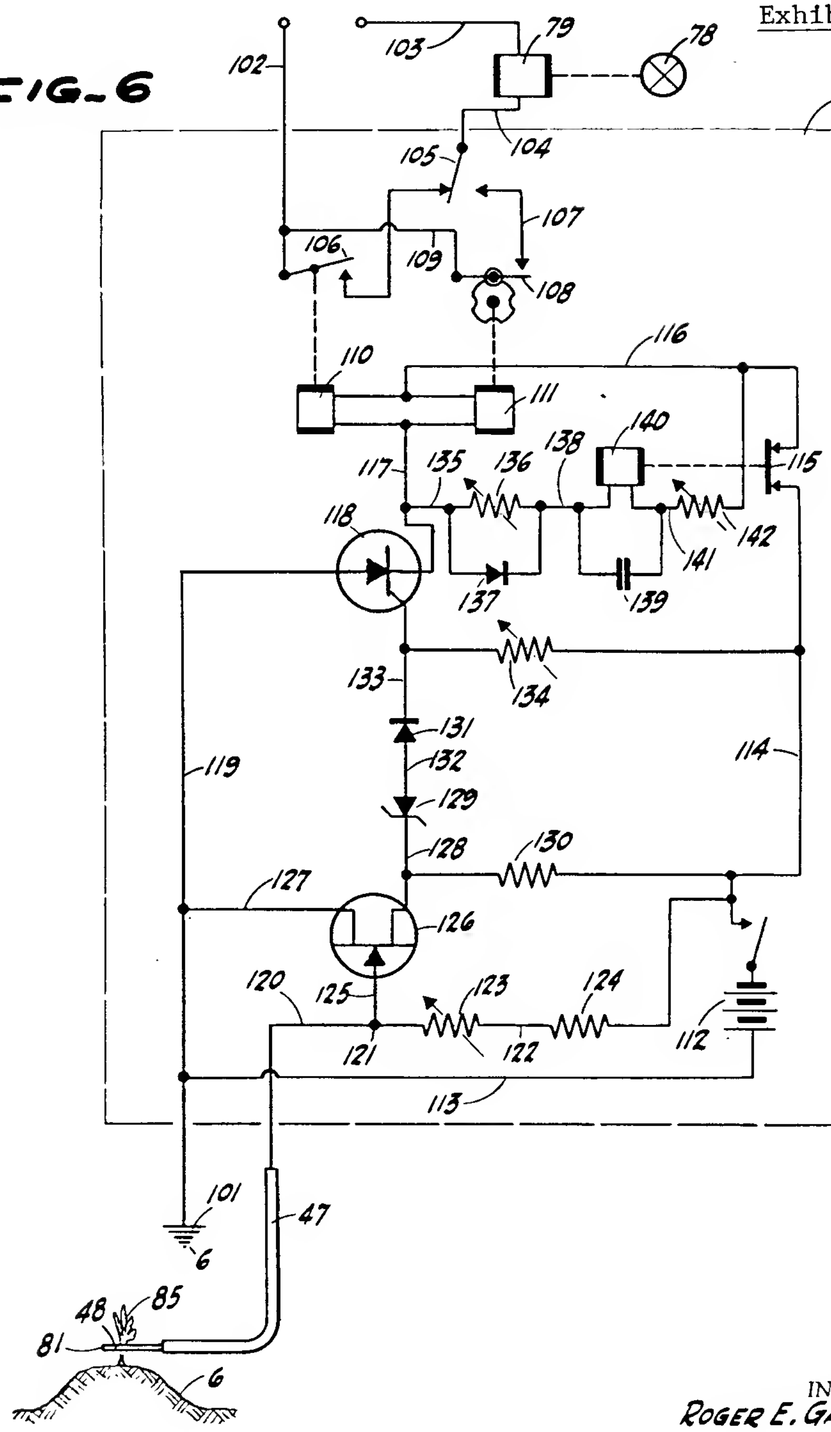
Exhibit C-1, continued

FIG-6



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3,358,775

PLANT THINNING MACHINE AND METHOD OF THINNING PLANTS

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Continuation of application Ser. No. 449,963, Apr. 22, 1965. This application Nov. 22, 1966, Ser. No. 596,344
4 Claims. (Cl. 172—6)

This is a continuation of application Serial No. 449,963, filed Apr. 22, 1965, and now abandoned.

My invention relates primarily, although not exclusively, to agricultural machinery and is particularly concerned with a mechanism and method by means of which the plants growing in a field after planting are reduced in number and spacing to a close approximation of a desired pattern.

In the cultivation of many plants; for example, lettuce and the like, it is customary to level the land quite accurately, particularly for irrigation, and to leave the land cultivated in furrows evenly spaced apart on opposite sides of parallel ridges. Lettuce seed is planted in the ridges in rows or lines generally straight and spaced apart a predetermined distance from the adjacent rows and with the furrows in between. Because of uncertainities in the emergence of seed, it is customary to plant in the row from twelve to fifteen times as many seed as would be requisite for the desired plants in proper spaced relationship if the emergence were one hundred percent successful. When the young plants then appear in the rows from those seeds that have emerged, it is customary to thin them by eliminating the plants intervening between those specimens which are to be permitted to grow to maturity. The retained plants are usually spaced apart an arbitrary distance; for example, one foot apart along the row or line.

Thinning has heretofore been practiced by manual means. This require a great deal of labor and particularly labor of a sort now difficult to get. There is, consequently, a demand for an improved mechanism and method for arriving at properly spaced, maturing plants and for eliminating intervening plants.

Machines for this purpose have heretofore been proposed. Many of them work by a technique of arbitrarily eliminating blocks of plants between geometrically predetermined sites. The difficulty is that sometimes a specimen does not actually occur at the expected geometrical site and an adjacent plant is removed which otherwise could be permitted to grow to maturity as a substitute. There has, consequently, been developed mechanism for sensing the occurrence of a plant in the row at any location and for then eliminating the adjacent plants. A difficulty has arisen, however, in that the sensing mechanisms employed if sufficiently sensitive are likewise upset by the general vibration and motion of the machine, so that signals are generated when none should properly be given, and great practical difficulties have arisen.

Other devices of this sort rely upon the use of electric eyes and comparable optical sensing devices. These are reasonably effective when they are clean, but normal operating conditions in the field, particularly dust, tend quickly to interrupt the satisfactory operation of the optical system. There is usually considerable unreliability connected with optical selecting means.

It is therefore an object of the invention to provide a plant thinning machine and method which are effective to sense the presence of a plant in a row and for removing adjacent blocks of plants, and which are not disturbed by random motion and vibration and are not adversely affected by dust or comparable deleterious ambient conditions.

Another object of the invention is to provide a plant

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thinning machine which can be utilized in connection with rows of plants as ordinarily planted and which is effective to remove a block of plants only when such block is adjacent a plant specimen that is to be preserved.

Another object of the invention is to provide a plant thinning machine which acts quickly and accurately to detect an appropriate specimen plant and to remove the adjacent undesirable plants.

Another object of the invention is to provide a plant thinning machine which depends for its operation upon the characteristics of a specimen plant itself.

Another object of the invention is to provide a plant thinning method which utilizes the plant itself as part of the selection step.

Another object of the invention is to provide an improved plant thinning machine.

Other objects together with the foregoing are attained in the embodiment of the invention and in the practice of the method thereof described in the accompanying description, the device being illustrated in the accompanying drawings, in which:

FIGURE 1 is a plan of one form of plant thinning machine constructed pursuant to the invention, the machine being shown in action in the field;

FIGURE 2 is a cross section, the planes of which are indicated by the lines **2—2** of FIGURE 1;

FIGURE 3 is a plan of a modified form of device pursuant to the invention;

FIGURE 4 is a cross section through a portion of the device of FIGURE 3, the plane of section being indicated by the line **4—4** of FIGURE 3;

FIGURE 5 is a fragmentary view showing in side elevation one form of plant removing structure; and

FIGURE 6 is a schematic diagram showing the electrical circuitry employed in connection with the structure.

While the plant thinning machine pursuant to the invention can be embodied in a number of different forms, it has successfully been operated in both of the forms shown herein. As shown in FIGURES 1 and 2, the structure is for use on the ground **6**, which has previously been prepared to provide ridges **7** and intervening furrows **8**. In each ridge there is provided a row **9** of plants. Usually two parallel lines or rows are planted, but for simplicity herein, but one line or row is shown located on the longitudinal center line of the ridge. The plants are of any sort, but for convenience are illustrated as lettuce. Eventually the plants must be spaced more or less evenly a large distance apart. Initially, enough seeds are planted so that the young plants are very close together, although some seeds may not grow at all, resulting in random gaps.

Designated to operate on the ground **6** is a carriage **11** including a metal frame **12** made up of a number of structural shapes supported on a pair of front wheels **13** and **14** and a rearward wheel **15**. Usually the wheels **13**, **14** and **15** are rubber tired. The frame is connected to the wheels by journals **16** and **17** carrying the wheel axles **18**. The carriage **11** is advanced in the direction of the arrow **21** in FIGURE 1 by any suitable propulsion mechanism represented by draft beams **22**. If desired, the carriage **11** can actually be constituted by a tool bar or comparable part of a tractor.

Adjacent its rearward portion, the frame **12** is provided with a supporting plate **23** overlying the rearmost wheel **15** and supporting an operating shaft **24** carried in bearings **26** and **27** and disposed in a horizontal plane. The shaft axis is at an angle to the line of the row **9** and to the direction of advance **21**. The shaft **24** carries a rotary disc **28** of a diameter so that the rim of the disc comes close to or even slightly below the upper surface of the ridge **7**. The disc for a portion of its periphery is interrupted to provide a window **29** of rectangular configuration extending in from the rim of the wheel and of

sufficient area to pass easily the largest size specimen with which the device is to work. The disc **28** when not rotating is locked or held in a "full cycle" position so that the window **29** is in a central position, as shown in FIGURE 2, and passes the plants freely.

The orientation of the disc is controlled by connecting a sprocket **31** on the shaft **24** by means of a chain **32** to a sprocket **33** on a clutch shaft **34**. The clutch shaft extends from a housing **35** encasing a single cycle clutch **36**. This clutch is not illustrated in detail, but is a standard commercial item. It has the characteristic of remaining locked in a set position until it is momentarily energized. Upon energization, the clutch is effective to drive the shaft **34** through exactly one revolution and then to lock the shaft in its full cycle position until another energization is received.

The single cycle clutch is mechanically driven. Extending from the housing **35** is a clutch drive shaft **37** connected through appropriate bevel gears (not shown) located in a housing **38** on the plate **23** to a drive shaft **39**. A belt **41** is in engagement with a pulley **42** on the drive shaft **39** and is also in engagement with a drive pulley **43** on the axle **18** of the rear wheel **15**. As the frame advances and the wheel **15** is revolved, the motion is transmitted by the belt **41** and through the bevel gears and the shaft **37** to the single cycle clutch.

As the carriage advances along the row **9**, the disc **28** remains fixed in its full cycle position until such time as an impulse is received to actuate the single cycle clutch. Thereupon the disc **28** revolves through one rotation as the machine advances. When the disc returns to its original location, it is again locked in full cycle position, pending the receipt of a further impulse.

Pursuant to the invention, particular means are provided for sending an appropriate actuating impulse to the single cycle clutch **36**.

Connected to the frame **12** is a housing **44** containing certain electrical equipment and on which is fastened an insulating support **46** engaging the insulating enclosure **47** of a probe **48**. The probe is an electric conductor **48** located within the casing **47** except that its end is completely exposed. The exposed end of the probe is disposed a short distance above the surface of the ridge **7** and is located so as to span the row **9** as the device advances.

The operation of the probe is in part dependent upon the height of a plant. If a plant is not sufficiently far above the ridge **7** as to be contacted by the advancing probe **48**, there is no signal. If the plant is sufficiently high, when the advancing probe **48** comes into contact with it, an electrical signal is given. This is preferably accomplished by completing an electrical circuit through the plant acting as an electrical conductor. The circuit is traced through the ground **6** and the machine frame **12**. The tires **13**, **14** and **15** are usually non-conducting rubber, insulating the frame from the ground. A metal disc **49** is mounted on the axle **18** of the rear wheel and digs into and forms an electrical contact with the ground and is connected to the other metallic parts of the frame.

The electronic circuitry within the housing **44** is such that when the probe comes even lightly into contact with a plant, an impulse is provided for the single cycle clutch **36**. It is not necessary to keep the probe particularly clean and free of dust and the like, nor is machine vibration important since the least abutment of the plant with the probe is sufficient to cause energization. It is true that an unwanted plant such as a weed can also actuate the probe, but in the usual case the wanted plants extend above the ridge farther than weeds do, so that by appropriate vertical adjustment of the probe and by utilizing the mechanism at the right time in the growing season, it is possible to eliminate virtually all extraneous weed influence.

It is also true that a clod or the like in the path of the probe and contacted by the probe will also trigger the single cycle clutch. In the usual field cultivation, however, the top of the ridge **7** is relatively smooth and devoid of clods so that it is unusual for an errant triggering to occur.

When triggered by a plant, the single cycle clutch **36** revolves the disc **28** through one turn. As soon as the window **29** has cleared the top of the ridge **7**, the periphery of the disc acts virtually as a plow and removes the upstanding plants from the ridge ahead of it and shunts such plants to one side into the furrow **8**. The disc continues to remove plants as the machine advances until such time as the window **29** is virtually back in its full cycle position. The next large plant passes through the window and itself then contacts the probe to actuate the clutch. In this fashion and with a steady advance of the machine, the disc upon each actuation is effective to remove plants from a predetermined distance along the ridge. At the end of that distance, should there be no upstanding plant, the machine will continue until such time as an upstanding plant passes through the window **29** and does come into contact with the probe, whereupon the removal operation repeats.

If there are plants in the row of insufficient height to be engaged by the probe **48**, these unwanted smaller plants are removed by a trailing blade **51** attached to the periphery of the disc **28**. The blade is behind the window and is sufficiently spaced behind the disc to afford adequate room for a plant of full size. The blade acts as a scraper to cut off plants in its path but is rotated away from a full-size plant that has contacted the probe.

In a modified form of the invention shown in FIGURES 3 and 4, the carriage and frame are substantially as previously described. There is attached to the frame **61** a longitudinally extending shaft **62** carried in bearings **63** and **64** and effective to oscillate about a longitudinal axis substantially parallel with the plant row **66**. Mounted on the shaft **62** and depending therefrom is a radially adjustable blade **67** having a branched lower end **68**. The blade is constituted either of a single portion or, as shown particularly in FIGURE 5, is constituted of a pair of portions **69** and **71** spaced apart in the direction of advance of the mechanism to leave a gap.

Extending from the shaft **62** is a crank arm **72** pivotally joined through a link **73** to the piston rod **74** of a pneumatic jack **76** including a cylinder **77**. The motion of the piston rod **74** is controlled by an air valve **78** on the jack **76** in turn controlled by a solenoid **79**.

Mounted on the frame **61** in a position trailing the blade **67** is a probe **81** comparable to the previously described probe. An electrically conducting central member is surrounded by an insulating cover **82**, except for a bare end, and is mounted on the frame as before. The probe is adjustable and is connected to electronic circuitry included in a housing **84** mounted on the frame. In this instance, when the probe **81** comes into physical and electrical contact with a plant **85**, a circuit is completed from the probe through the ground, then through a grounding plate **86** to the frame of the machine to which the probe circuitry is connected. When the circuit is closed, the solenoid **79** is actuated by the electrical impulse and the air jack **76** is effective to reciprocate the blade **67** in either of two modes.

In one mode, the blade is reciprocated from right to left, in FIGURE 4, from the full line position into the dotted line position. This transverse motion sweeps out all of the plants or a block of plants immediately ahead of the plant **85** that contacted the probe **81**. Following this, the knife **67** sweeps back from left to right to its initial position and stops. In the other mode of operation, the blade **67** sweeps from the right-hand position to the left-hand position and then stops. The next impulse then causes the blade to sweep from the left-hand position back to the right-hand position and stop. If all of the trash, removed plants and earth, is to be in one furrow, the blade **67** makes a complete excursion in both directions. If trash is to be deposited in both furrows, then the blade makes an excursion in only one direction for each impulse.

If the form of blade particularly shown in FIGURE 5

is utilized, then the blade not only removes a block of plants in advance of the selected plant, but also the blade sweeps or re-sweeps the area in the row behind the selected plant. There may be some overlapping of the swept areas, but there is asurance that a predetermined free area is afforded both ahead of and behind the selected plant.

In both forms of the invention, the electronic circuitry utilized is substantially as shown in FIGURE 6. The frame of the machine operates at ground potential, as indicated by the frame ground **101**. A source of current at a relatively high voltage; for example, one hundred ten volt alternating current, is provided across a pair of conductors **102** and **103**. The conductor **103** extends to the solenoid **79** which actuates the air valve **78**. A lead **104** connects the solenoid **79** to a selector switch **105** which has two optional positions. In the position shown, the switch **105** connects through a conductor and a switch **106** to the conductor **102**. When the switch **106** is closed, the solenoid is energized to operate the valve **78** so that the jack completes an outstroke and an instroke. In other position, the switch **105** connects through a conductor **107** and a switch **108** as well as a conductor **109** to the conductor **102**. When the switch **108** is first actuated, it operates the valve **78** so that the jack completes an outstroke. When the switch **108** is next actuated, it operates the valve **78** so that the jack completes an instroke. Thus, the switch **105** controls the two modes of operation of the blade portions **69** and **71**. When the disc **28** is used, the solenoid **79** is arranged to operate the single cycle clutch **36**, and the switch **105** and the switch **108** are omitted.

The switch **106** is operated by a solenoid **110** while the switch **108** is operated by a solenoid **111** connected in parallel with the solenoid **110** in an electrical circuit operating with direct current at a low voltage and entirely isolated from the high voltage circuitry. A battery **112** is connected by a conductor **113** to ground **6**. This is an actual earth connection through the disc **49** or the plate **86**. The other side of the battery is joined by a conductor **114** to one side of a switch **115**. The other side of the switch **115** is connected by a lead **116** to one side of the two solenoids **110** and **111**. The other side of the solenoids **110** and **111** is joined by a conductor **117** to the cathode of a silicon controlled rectifier **118**, the anode of which is connected to ground by a conductor **119**.

The probe **48** (or **81**) connects through a lead **120** to a junction point **121** from which a conductor **122** containing a variable resistor **123** and a fixed resistor **124** extends to a junction with the conductor **114**. Also from the junction point **121** a lead **125** connects to the gate of a field effect transistor **126**, the drain of which is joined by a lead **127** to the conductor **119** and the source of which is connected to a lead **128** extending to a Zener diode **129**. A resistor **130** is connected to the lead **128** and to the conductor **114**. A diode **131** is connected in the opposite direction to the Zener diode by a connector **132** and is connected to the emitter of the transistor **118** by a conductor **133**. A variable resistor **134** is connected to the conductors **133** and **114**.

From the conductor **117** a lead **135** branches to connect respectively to a variable resistor **136** and to a diode **137**, both connected to a lead **138** that in turn branches to connect to one side of a capacitor **139** and to one end of a switch coil **140**. A connector **141** joins both the other side of the capacitor **139** and the other end of the switch coil **140** through a variable resistor **142** to the lead **116**.

This circuit is stable and quiescent until a plant or similar object contacts the probe **48** (or **81**). Thereupon energy is supplied to the solenoids **110** and **111** to actuate the switches **106** and **108** and to produce whichever mode of air jack operation is selected by the switch **105**. Energy is also supplied to the switch coil **140** so that shortly after the coils **110** and **111** have acted the switch **115** is opened and the circuit is restored to quiescence. The time delay is governed by the resistors **136** and **142** so that an inadvertent contact with the probe too soon after an actuation thereof is ineffective.

The sensitivity of the electronic circuitry varies with the values of the circuit components. It has been found in practice that an extremely sensitive response can be had to the presence of a plant against the probe. Yet this same sensitivity does not in any wise cause an actuation of the solenoid air valve or of the single cycle clutch because of vibration or motion or shaking of the mounting machine. In fact, the use of the electrical properties of the plant is effective to preclude operation of the structure by any normally encountered disturbing forces. It has also been found in practice that the sensitivity of the arrangement is such as not to be unusually affected by the short-term variations in moisture content of the plant or in moisture content of the ground, the average agricultural conditions or the normal variation therein all being sufficient for operation of the structure.

The sensitivity of the circuitry can be made such that the return current through the ground to the ground conductor **101** may be exceedingly slight, in fact so slight as to indicate that the factor which unbalances the circuit and causes the triggering action is not so much the conduct of electricity through the plant, but in many instances is merely the body capacity of the plant itself. That is to say, an abrupt change in capacity made manifest in the lead **120** is sufficient to cause triggering of the circuitry and operation of the structure. In fact, under some conditions, the ground connection **101** can be omitted and the contact of a plant with the probe **48** (or **81**) will trigger the operation of the solenoids **110** and **111**.

The electronic circuitry has its own battery **112** and is electrically isolated from the usual electrical equipment found on a draft tractor or comparable mechanism since stray currents in the framework may trigger the mechanism when triggering is not wanted. By varying the sensitivity of the electronic circuitry, either the return flow current through the plant and the ground or the capacity effect of the plant when contacted can be used separately or can be combined.

What is claimed is:

1. A plant thinning machine for use with a row of plants growing in the ground comprising a frame adapted to be advanced over said ground along said row, a shaft, means for mounting said shaft on said frame for limited oscillation about an axis extending lengthwise of said row and situated directly above said row of plants, a blade mounted on said shaft and disposed in a plane containing said axis, said blade having a length substantially equal to the length of a block of said plants to be removed from said row and having a radial dimension terminating substantially at said ground in the central position of oscillation of said blade in a position to dislodge some of said ground into the vicinity of said plants as said blade oscillates, an electrically conducting probe, means for mounting said probe on said frame to extend transversely of said row in a location slightly above the ground and just to the rear of said blade in a position in the path of some of said ground dislodged by said blade, means for oscillating said shaft to swing said blade from a first position on one side of said row through said row to a second similar position on the other side of said row, an electrical circuit including said probe and a return portion and adapted to be completed through said plant and said return portion by contact of said probe with a particular plant in said row, and means responsive solely and immediately to completion thereof to operate said oscillating means to make one swing of said blade, beginning at said first position and ending at said second position just ahead of said particular plant.

2. A device as in claim **1** in which control means are provided for selectively conditioning said circuit to swing said blade from said first position to said second position in response to one contact of said probe with a plant and then swing said blade from said second position to

said first position in response to a subsequent contact of said probe with another plant or for swinging said blade from said first position to said second position and immediately back to said first position in response to each contact of said probe with a plant.

3. A device as in claim 1 in which a second blade substantially a duplicate of said first blade is mounted on said shaft coplanar with and rearwardly of said first blade, said first blade and said second blade being spaced axially apart to accommodate said probe and one of said plants between them.

4. A device as in claim 1 in which means are provided for retaining said blade either in said first position or said second position except when said oscillating means is operated in response to contact of said probe with a plant.

References Cited

UNITED STATES PATENTS

225,890	3/1880	Sustaire	172—73 X

8

1,468,244	9/1923	Marable	172—73
2,592,689	4/1952	Hann	172—6
3,023,815	3/1962	Bowman	172—5
3,308,890	3/1967	Rhode	172—6
2,535,720	12/1950	Boncompain.	
2,664,802	1/1954	Myer	172—6
2,804,004	8/1957	Hubalek et al.	172—6
3,097,702	7/1963	Cracknell et al.	172—6
3,181,618	5/1965	Miller	172—6
3,233,681	2/1966	Ferte	172—6

FOREIGN PATENTS

869,881	3/1953	Germany.
900,280	7/1962	Great Britain.

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